IN my former letter in NATURE of January 6 I attempted to prove that the arrangements of dots in a band would occur even if the numbers of which the sums were taken were entirely independent of one another, in which case a forecast regarding one of the numbers could not possibly be made from knowledge of the remainder. A forecast could only be made if it were shown that the width of the band were smaller than would be expected on the hypothesis of pure chance, and this vital point has received no consideration.

The situation may be made clearer by reference to the original letter in NATURE of September 16, 1909. The essence of the method is that, if we were forecasting for 1910, the dot the two rectangular coordinates of which are the sums of data for thirty years up to 1909 and 1910, respectively, will lie near to a line through the origin at an angle of 45° with the axes. Thus the sum of the data from 1880 to 1909 will be *nearly* equal to the sum of the data from 1881 to 1910, or the data for 1880 and 1910 will be *nearly* equal. If the *nearness* to equality has any value at all for forecasting, this is equivalent to asserting that the data in question tend to be repeated after thirty years, or have a thirty years' period; but as the same result could be reached if 25 or 35, or any other comparable number, had been substituted for 30, it will be seen that the reasoning cannot be free from error.

That the nearness to equality is inadequate is clear from the diagram in the original letter. The edges of the band there intercept a length representing about thirty-six days along any vertical ordinate. Hence all that can be inferred in forecasting for 1910 is that the number of hot days will probably not differ by more than ± 18 from the number of hot days in 1880; and as the average number of hot days in a year is stated as fifteen, it appears that a forecast so entirely vague could be made without any analysis whatever.

GILBERT T. WALKER.

Kodaikanal, February 21.

SOME SCIENTIFIC CENTRES.

No. XV.—THE MOUNT WILSON SOLAR OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON.

MOUNT WILSON rises 6000 feet, almost abruptly, from the plain in which lie the twin cities of Los Angeles and Pasadena. From the mountain top these cities appear at night as glittering star clusters; by day they are seen through a haze of dust which the ascent of the mountain has put below our feet. Beyond is the vast Pacific; above our heads the glorious sky of California; around us the buildings of perhaps the best equipped observatory in the world.

These words are written by anticipation. Prof. Hale has invited the International Union for Solar Research to hold its next meeting on Mount Wilson on August 29, 1910, and astronomers and physicists from all parts of the world are eagerly looking forward to the occasion. The present writer is not, however, altogether a stranger to the scene; he was on Mount Wilson in 1904; but at that time the observatory was in its infancy. It had not even been decided on what scale it was to be designed. Prof. Hale had realised the magnificent opportunities offered by the climate and site, and he had made urgent application to the Carnegie Institution for funds adequate to deal with the serious difficulties to be overcome; but he had also resolved that, if his application was not granted, there should still be a solar observatory on Mount Wilson, for which he would himself provide the funds, so that he had already commenced building operations. Nevertheless, the utmost provision which he and his courageous wife could afford to make would naturally fall far short of what was needed for a suitable observatory, and he was therefore anxiously awaiting the answer of the Carnegie Trustees. Fortunately for astronomy, it was favourable; and since it was received one marvel has followed another in rapid succession. The visitors will be drawn to Mount Wilson as to the main focus of astronomical enterprise and success at the present moment.

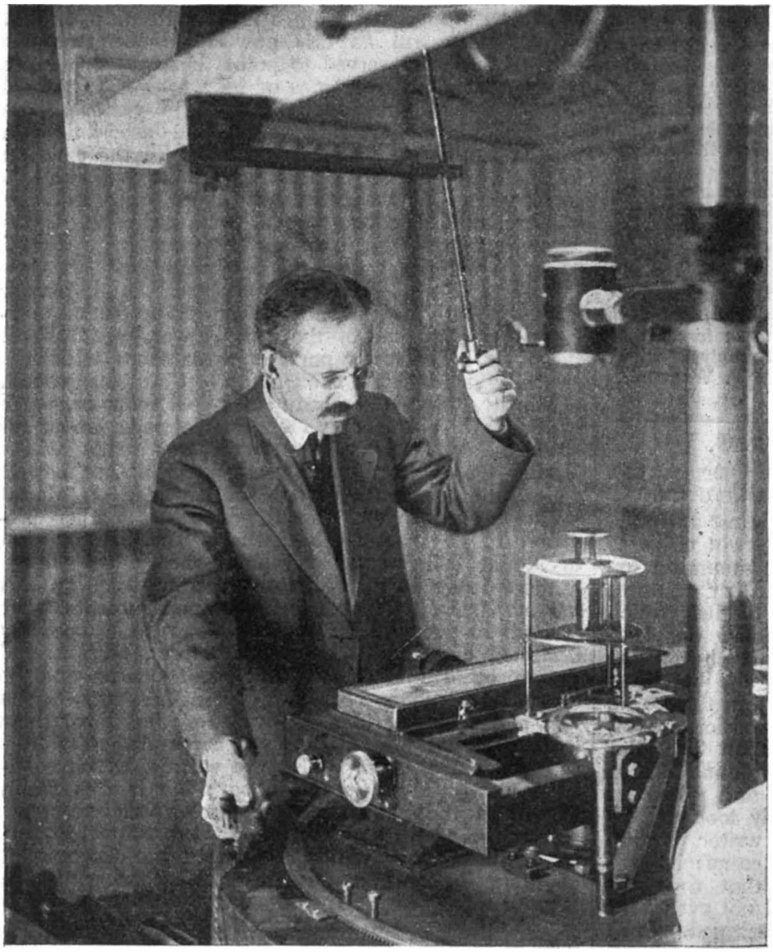
The first of the principal instruments to be completed was the great horizontal Snow telescope, originally constructed at the Yerkes Observatory, with the aid of funds given by Miss Snow, of Chicago. The concave mirror, of 24 inches aperture and 60 feet focus, is fed by a cœlostat with plane mirrors of 30 inches and 24 inches, the beam of light being sheltered by a house specially designed to guard against temperature effects. To this telescope can be attached a spectrograph of 18-feet focus, or a 5-foot spectroheliograph. The heavy parts of the apparatus are mounted on massive stone piers, built with great labour, since it was found that the stone in the neighbourhood was unsuitable, and that materials had to be brought up from a lower altitude by mules.

But, successful as this powerful instrument has been, it has also served to point the way to possible improvements. Experience of its working suggested that a *vertical* telescope might be in various ways better than a horizontal one; and accordingly a "tower" telescope was constructed, with the cœlostat mounted on a tower 60 feet high, built as a skeleton framework. This experiment was so successful that a more ambitious one was at once projected, and a tower 150 feet high is under construction. As wind pressure will be much more serious on this new structure, Prof. Hale has adopted the ingenious device of building an outer tower for protection, surrounding every bar of the inner tower by a tube of the outer. The lower parts of these tower telescopes are contained in wells sunk many feet into the ground.

Thirdly, there is the beautiful 5-foot reflector, made by Prof. G. W. Ritchey, who has already proved his skill in such work. The mirror was made at the Yerkes Observatory some years ago, but has had to wait until a mounting could be provided on Mount Wilson; and, indeed, there was a still earlier provision to be made; the track up the greater part of Mount Wilson was originally only 3 feet wide—a mere ledge in a precipitous descent—and up this narrow track the materials and instruments were carried, at first on mule back, later in a specially designed carriage, with steering fore and aft, and drawn by a mule. But the 5-foot mirror and its mounting could not be taken up in this way, and it was necessary to widen the track to 5 feet throughout its whole length. This was not accomplished without serious delays, owing to severe storms, which sometimes destroyed weeks of labour; but it was finally completed, the instrument was taken up and mounted, and at the meeting of the Royal Astronomical Society on December 10, 1909, were shown some photographs of Mars taken with this great telescope which far surpassed anything of the kind yet seen, and for which the president was requested to convey a special vote of thanks.

A still larger telescope, with a mirror 100 inches in diameter, is to be attempted on Mount Wilson, but is not yet within sight of completion. Round the existing three great instruments are grouped a number of other buildings; first and foremost a physical laboratory, so indispensable now in astrophysical work; also an astrophysical museum, and a variometer house; and then such necessary accompaniments as a power-house, a pump-house, storage-houses, and dwellings. The establishment is not adapted for ladies and children, and the chief residence is called the "Monastery." Distressing news reached us recently that the "Monastery" had been burnt down, owing to the carelessness of a temporary servant. Fortunately it contained no original photographs or records, and most of the books had been taken down to Pasadena, but many were burnt. The building and contents were insured, but re-building cannot be commenced until after the close of the rainy season in the spring, so that the observers will be put to some inconvenience during the next few months, though there are now so many residences on the mountain that they can find temporary quarters.

In Pasadena, 6000 feet below, are the instrument shop, office, physical laboratory, &c. Here also dwell the wives and families of the observers. There is, of course, communication constantly by telephone and frequently by personal visit between the two departments of the observatory. Much practice has made the observers expert and rapid climbers.



Prof. G. E. Hale at the 30-foot spectrograph of the 60-foot tower telescope, arranged for photographing the spectrum of a sun-spot with rhomb and Nicol prism.

Our thoughts naturally turn from the contemplation of so magnificent an installation to the man who designed it, and has brought it to such perfection of efficiency in the short space of six years. It is, of course, not the first achievement of Prof. Hale. Just six years ago it fell to the lot of the present writer to review his work on the occasion of the award to him of the gold medal of the Royal Astronomical Society. That work already comprised the successful inception of the spectroheliograph and its use in depicting the "flocculi" at various "levels" in the solar atmosphere (the connotations of the terms in inverted commas having been suggested by the medallist only a few weeks before); also a considerable piece of work on the spectra of fourth-type stars; also the foundation and equipment, not only of the private observatory at Kenwood (Chicago), but of the great Yerkes Observatory, with its giant telescope and other magnificent resources for the study of astrophysics; also the establishment of the *Astrophysical Journal* as an indispensable aid to workers. Such a record might well have contented an ambitious man at the end of a long life, but it is not too much to say that Hale has in the intervening six years eclipsed these achievements, together and separately, by new ones. The workers who had been put in communication by his Journal have been drawn into closer companionship by the International Union for Solar Research, which he inaugurated at St. Louis in 1904, and which he has invited, after meetings at Oxford (1905) and Meudon (1907), to meet at Mount Wilson this year, as above stated. His record of work now includes the photographic mapping of the sun-spot spectrum (a long-standing problem solved) and the discovery of magnetic vortices in the sun—a truly sensational discovery, and one which is certain to lead to others; and his work in founding the Yerkes Observatory has been treated as preliminary to the real business of adapting the splendid Mount Wilson Observatory, point by point, to the pressing needs of solar physics.

We should lose a valuable lesson if we did not note the steady progression in enterprise which has built up the success. Prof. Hale has several times publicly insisted upon the value of work with modest apparatus, such as he began with himself. During a visit to England in 1907, he gave an address to the Royal Astronomical Society on "Some Opportunities for Astronomical Work with Inexpensive Apparatus" (Mon. Not. R.A.S., lxviii., p. 64), which not only emphasised the value of such work, but gave a number of concrete suggestions to intending workers. The difficulties of making a beginning are well known; but those who earnestly consult this lecture will find most of them removed. It is, of course, assumed that there is a desire to work; Hale addressed himself to "the amateur," defining him as "the man who works in astronomy because he cannot help it, because he would rather do such work than anything else in the world, and who therefore cares little for hampering traditions or for difficulties of any kind." These noble words are not only a stimulus; they also clearly reflect the character of the man who uttered them, and go far towards explaining his success. For the rest, we may accept his own estimate of the importance of beginning with small means, and of the value (several times emphasised in letters to the present writer) of the encouragement of his father. His father bought him a telescope (an excellent 4-inch Clark), but not until he had first made one himself; his father also bought him the spectroscope with which he first photographed a spectrum, to his huge delight, but this was not until he had first worked with home-made apparatus; his father built the Kenwood Observatory, but not until his son had matured his plans by work at Harvard and elsewhere. "His policy always was," writes the son in one of his letters, "to induce me to construct my first apparatus, and then to give me a good instrument if my early experiments were successful." On the death of this wise and kind father, his children established, in pious and affectionate memory of him, the "William E. Hale Fund" for the encouragement of research, which has already aided, in an unobtrusive but none the less efficient manner, several scientific projects of different kinds. His lessons are so deeply impressed on the mind of his son that in the address above referred to he said, "with all seriousness, that it is a fair question whether large observatories, with powerful instrumental equipment, should be established, if they tend to keep back the man who is pursuing the subject with less expensive appliances, and is introducing, through his careful consideration of the possibilities of research, the new methods which in the process of time will take the place of the old ones."

A few facts and dates may be given here. George Ellery Hale was born in Chicago on June 29, 1868 (a few months before the classical observations of prominences without an eclipse, on which he was to build his main work), the son of William E. and Mary S. Hale; he married in 1890 Miss Evelina S. Conklin, of Brooklyn, N.Y., and has a daughter and a son. He entered the Massachusetts Institute of Technology (Boston) in 1886, taking the course in pure science, and graduating S.B. in 1890. He spent some time at the University of Berlin in 1893–4. While in Boston he was enabled, by the kindness of Prof. E. C. Pickering, to spend his spare time at the Harvard Observatory, doing any work assigned to him. The principle of the spectroheliograph occurred to him in the summer of 1899, but experiments were not then successful. He first photographed the prominences in the spring of 1891, within a week or two of similar successes by C. A. Young and Deslandres; but this achievement must be carefully distinguished[1] from the construction of the first successful spectroheliograph, in which Hale had a clear lead of all other workers. It was completed in January, 1892, and from that time regularly recorded, at the Kenwood Observatory, prominences and faculæ. Before the end of 1892 the project for the great Yerkes Observatory was already on foot, and was completed in the autumn of 1897. We may note in passing two incidents of that early history; first, that the project originated in a chance conversation with Alvan G. Clark at the Rochester meeting of the American Association for the Advancement of Science. Hale then learnt of the existence of two discs of glass available for a large telescope, and immediately began the search for a Mæcenas. Such incidental results of scientific gatherings are sometimes forgotten in estimating their value. Secondly, after several applications had failed, when ultimately the matter was laid before the late Mr. C. T. Yerkes, he replied at once, inviting President Harper and Mr. Hale to call upon him, and telegraphed for Mr. Clark as a result of the interview. His rapidity in decision seems to have been noteworthy, even in Chicago.

It would unduly extend this brief notice to follow the history of the Yerkes Observatory during the years from its completion in 1897 until Hale handed over the directorship in 1904 to Prof. E. B. Frost, in order to devote himself to the Mount Wilson Observatory. One is sometimes tempted to peer into the future; from Kenwood to Yerkes, from Yerkes to Mount Wilson, from Mount Wilson to ——? Does a fourth term of the series ever occur to Prof. Hale in his dreams? Series are treacherous to deal with; "it is most unpleasant," once remarked an eminent mathematician who has devoted part of his life to them, "to dream that you are expanded in an infinite series, and that it will not converge." There is a notable divergence in the series of observatories with which Prof. Hale might identify himself; but then it may not be infinite. Indeed, we expect to find —recurring to the attitude of anticipation with which this notice began—we confidently expect to find in August next excellent reasons why the series should stop short at its third term. It is difficult to imagine how conditions for work could be bettered. Mount Wilson has great instruments and a fine climate; it has the financial backing of the wealthy Carnegie Institution; it is within easy reach of Pasadena, and in telegraphic communication with the whole world; and last, but by no means least, it has already an able staff of workers, including men like Adams, Ellerman, and Ritchey, whose names are famous wherever there is an astronomer. Those who have visited the mountain are enthusiastic in praise of the conditions for work. A notable visit was paid by Prof. Barnard, who found the times of exposure required for his photographs considerably less than at the Yerkes Observatory.

The main purpose of the Mount Wilson Observatory is solar research, but a wide interpretation must be given to the term. Prof. Hale has often emphasised the representative character of the sun—it is the one star near enough to be examined in detail; but it is nevertheless a star, and to understand it we must study it alongside other stars; we cannot do justice to the sun by working at the sun alone. Hence he has insisted on an adequate equipment for stellar work at Mount Wilson. The method of attacking scientific problems along more than one line is a characteristic feature of Hale's work generally, and has been an important factor in his success. To give a recent and striking instance. Along one line he was developing the spectroheliograph to the point where good photographs could be obtained in red light (Hα), and this led to the discovery of the solar vortices; along another line, which might have seemed irrelevant to the former, he was working at the photography of sun-spot spectra, and at last succeeded in getting good images of double and triple lines. Forthwith the two researches met and flowed in the same stream; to test the magnetic hypothesis of the vortices he could examine the spot spectra polariscopically. Had either of these two lines of work been neglected, the other would have remained unfruitful. No doubt there was an element of luck in the simultaneity with which the two became available; but luck proverbially attends on energy and enterprise.

H. H. TURNER.

THE BRITISH SCIENCE GUILD.

THE fourth annual meeting of the British Science Guild was held at the Mansion House on March 18, when the fourth annual report upon the work of the past year was presented. The Lord Mayor occupied the chair, and an address was delivered by Mr. Haldane, president of the Guild. Sir John Cockburn, K.C.M.G., gave a summary of the report, the adoption of which was moved by Lord Strathcona, and seconded by Sir Alfred Keogh, K.C.B. Sir George Darwin, K.C.B., and Sir Ernest

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[1] It does not seem to the present writer that the late Miss A. M. Clerke has been sufficiently careful to distinguish these two distinct steps in her otherwise admirable writings (see, *e.g.*, "Problems in Astrophysics," pp. 18 and 98.